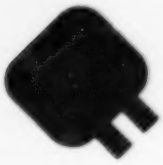

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Entrainment Mortality of Rainbow Smelt Larvae at Nanticoke TGS in 1982

Report No. 83-339-K

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ABSTRACT

The objective of this study was to determine the mortality of rainbow smelt larvae resulting from plant passage (entrainment) at Nanticoke TGS. Fish larvae were collected from the intake forebay and immediate discharge using conical nets from May 11 to June 15, 1982. None of the larval smelt collected in the discharge samples were alive and a large portion of these larvae were found to be physically damaged. In the intake forebay live larval smelt were only caught on four of the fourteen days on which smelt were collected. Although many smelt larvae may be dead prior to passing through the station, mortality due to passage through the station was estimated to approach 100%. However, it is cautioned that higher net approach velocities in the discharge may account to some extent for the higher mortality in the discharge samples such that entrainment mortality estimates may be magnified.

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To Mr. D.K.A. Gillies
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ENTRAINMENT MORTALITY OF RAINBOW SMELT LARVAE AT NANTICOKE TGS IN 1982

1.0 INTRODUCTION

An investigation into the mortality of larval fish as a result of passage from the forebay through the condenser cooling system to the discharge (pump entrainment) was conducted at Nanticoke TGS from mid May to mid June, 1982. The study was requested by Central Thermal Services, Thermal Generation Division of Ontario Hydro. Nanticoke TGS, situated on Long Point Bay, Lake Erie, consists of eight coal fired units with a total capacity of 4000 MW. Condenser cooling water to the eight generating units is supplied by two CCW pumps per unit.

The operation of Nanticoke TGS requires large volumes of water for its condenser cooling water system. At full capacity (4000MW) it draws water from Lake Erie at a rate of 152 m^3/s through two intakes located 650m offshore at a depth of 10m into its intake forebay. Of this, 89 m^3/s is required for condenser cooling and the remaining 63 m^3/s is used as tempering water to reduce the temperature of the effluent.

The condenser cooling water passes through condenser tubes 15 m long with outer diameters of 3.0 cm at a rate of 1.2 m/s. The maximum design temperature rise across the plant is 13.1 C and the back pressure is 5.1 kPa. The larval fish entrained in the cooling water are subjected to mechanical stress, abrupt temperature increase, and sudden pressure changes.

Mortality of entrained larval fish has been reported by numerous researchers although the ranges of mortality have been wide and generally based on quantitatively limited data. Marcy (1975) in reviewing the literature on this topic found mortalities of between 39 and 100% with most researchers reporting 100%. Marcy (1973) found that fish seem to be vulnerable to the mechanical stress encountered in condenser passage. In a study that he conducted he estimated that 80% of the mortality of the young of

nine species entrained at the Connecticut Yankee Plant was caused by mechanical damage. Larval fish entrainment mortality reported in the literature since Marcy's review includes King's (1977) work at the Fort Calhoun station where he estimated the mortality of larval fish, mainly freshwater drum, to range between 10 and 40%. Stevens and Finlayson (1977) reported mortalities of striped bass at the Pittsburgh Power Plant to range between 0 and 100% and at the Contra Costa Power Plant to be 21 to 100%. Cannon et al (1977) reported entrainment mortality at six Hudson River power plants to range from 0 to 30%. In a study conducted at Pickering NGS in 1981 larval rainbow smelt mortality was estimated to be between 0 and 39% immediately following condenser passage and between 0 and 52% 24 hours following condenser passage (Ontario Hydro Research Division Report No. 82-55-K).

In a study investigating the species composition and abundances of entrained larval fish at Nanticoke TGS it was estimated that 100 million rainbow smelt larvae were entrained by the condenser cooling system from May through August, 1981 (Ontario Hydro Research Division Report No. 82-55-k). Rainbow smelt constituted approximately 94% of the total number of larval fish that were entrained. Smelt larvae entrained at Nanticoke TGS in 1981 were equated to the reproductive potential of 721,500 adult females which were estimated to represent between 1 and 6% of the Canadian commercial catch of this species in Lake Erie (Ontario Hydro Research Division Report No. 82-55-K). However, the impact of the cropping of large numbers of fish larvae by the condenser cooling water system on the lake population is not known.

The objective of this study was to determine plant passage mortality of rainbow smelt larvae at Nanticoke TGS which could be used in future assessment of impact on these populations as a result of entrainment.

2. METHODS

Homelite Trash pump and net-in-tank systems were used to collect larval fish from the Nanticoke TGS intake forebay and discharge on June 9, 10, 11, 14 and 15, 1981, for the determination of entrainment mortality. Collection using this system reduces the handling stress suffered by the larvae during sampling (OHRD Report No. 83-312-K). Three 60 minute samples were taken at both the intake and discharge on each of the five days. However the densities of the larvae were insufficient for the use of this system and over the five day period only two larvae, both of which were dead, were taken in the intake forebay pump and net-in-tank system on June 14. The mean flow rate of the pump and net-in-tank systems achieved during the course of the study was 0.32 m^3/minute. This was the speed at which upwelling of water in the tank was prevented and the nets remained intact and in proper position. Due to the problems encountered with the net-in-tank system it was decided that larval nets would be employed to collect the samples. Consequently results presented and discussed are based on data collected with larval nets.

Larval fish were collected using 363 µm mesh conical nets with an open end diameter of 0.5 m and a length to diameter ratio of 3:1. The nets were equipped with General Oceanics flow meters (model 2030). Samples were taken daily except for weekends for approximately a five-week period from May 11 to June 15, 1981, from both the intake forebay and the immediate discharge.

At the intake the nets were suspended in the center of the channel in front of the pump house servicing units 3 and 4 (Figure 1). Samples collected to estimate larval fish densities from May 11 to 31 consisted of 30 minute tows. When live-dead determinations were initiated on June 1, the time was reduced to 10-15 minutes in order to reduce the physical stress experienced by the larvae during sampling. Initially, 5-minute tows were attempted; however, due to the low larval fish densities, these tows were ineffective and sampling times were increased.

Discharge samples for live-dead determinations were taken by suspending the nets into the immediate discharge from the discharge platform for 10-minute intervals.

Species composition and seasonal densities of the larval fish presented are based on intake samples. Larval fish collected in the intake forebay represent the larvae that are being entrained while those collected in the discharge may include those spawned in the discharge channel in addition to those that were entrained. Discharge samples were only used to estimate entrainment mortality.

From June 1 to June 15, with the exception of week-ends, at least six samples were taken daily from each of the intake forebay and immediate discharge for the determination of larval smelt entrainment mortality.

Fish larvae were sorted as alive or dead on the basis of motility. Immobile larvae that did not react to gentle probing were classified as dead. Since a large number of dead larvae in the discharge samples were severed, only pieces with heads attached or segments without heads covering at least two-thirds of the body length were counted. Live larvae were removed by pipette and placed in 500 ml wide-mouthed polyethylene containers equipped with two 20 µm mesh Nitex windows which kept the larvae in the container but allowed for water circulation. These containers were placed in tubs located along the pump house (for units 3 and 4) which were supplied with a continuous flow of intake water. The larvae were observed again after a 24 hour incubation period to determine latent mortality.

All larvae were preserved in Davidson's B solution and placed in appropriately labelled bottles for recounts and positive speciation in the laboratory.

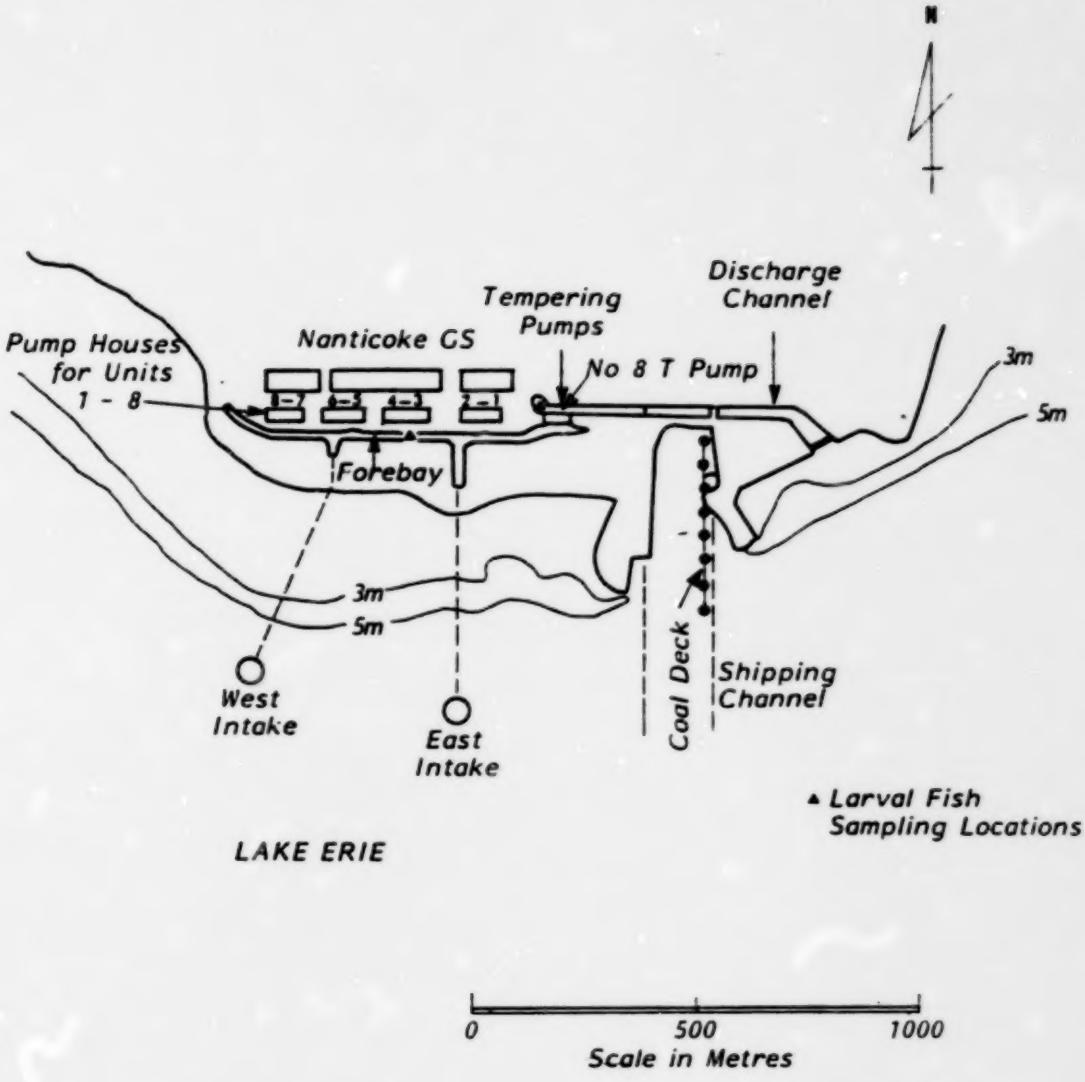

FIGURE 1

NANTICOKE TGS
INTAKE FOREBAY AND DISCHARGE
LARVAL FISH SAMPLING LOCATIONS

Larval fish densities were calculated using the following formula:

$$LOWC = 0.026 \text{ (flow meter reading)} + 0.049$$

$$\text{Density (No } m^{-3}) = n/LOWC \ (3.142)(0.0625)$$

LOWC is the length of the water column passed through the net and n is the number of larvae caught. Density estimates could not be calculated for June 10 and 11 because the flow meter was lost into the discharge current.

Entrainment mortality was calculated using the formula

$$M = (1 - D/I)\ 100$$

where M is mortality, D is the mean per cent alive in the discharge (test) samples and I is the mean per cent alive in the intake (control) samples (Stevens and Finlayson 1977).

The proportion of live rainbow smelt larvae in intake and discharge samples collected on June 2, 3, 7 and 8 were compared using the 2X2 Contingency Chi-square Test (Seigel 1956).

3. RESULTS

A total of 263 larval fish were collected from the Nanticoke TGS intake forebay between May 11 and June 15, 1981 (Table 1). With the exception of a single burbot larva (0.4%), all the larval fish taken in the intake forebay were rainbow smelt (99.6%).

Table 1

Species Composition of Fish Larvae Collected from The Nanticoke TGS Forebay between May 11 and June 15, 1982.

Species	Number Caught	Per Cent Composition
Rainbow Smelt	262	99.6
Burbot	1	0.4

Table 2

Densities of Rainbow Smelt Eggs Entrained at Nanticoke TGS from May 11 to June 15, 1982.

Date	Number Caught	Density (No./1,000 m^3)
May 25	2	10.0
May 26	4	13.8
May 27	1	8.3
June 9	3	173.8

Rainbow smelt larvae were absent from the Nanticoke TGS intake samples on the first sampling occasion, May 11, through to May 26. Their densities then increased between May 27 and June 3 to an estimated 1,226/1,000 m^3 (Figure 2). A subsequent decline in numbers resulted in a low density of an estimated 815 smelt larvae/1,000 m^3 on June 9. Highest abundance was estimated on June 15 when their density was estimated at 1,306/1,000 m^3. Sampling was discontinued at this point as scheduled.

Only seven rainbow smelt eggs were caught in the intake forebay during May (Table 2). These eggs were taken between May 25 and 27 with densities on these three dates estimated to be less than 14/1,000 m^3. Eggs were caught again on June 9 when highest mean density of 174/1,000 m^3 was estimated.

Live larvae were only found on four of the fourteen days on which smelt larvae were collected in the forebay. The per cent of live larval smelt in the intake forebay samples immediately following collection on June 2, 3, 7 and 8 were 8, 31, 15, and 6%, respectively (Table 3). Following a 24 hour incubation period the percentages for larvae collected on June 7 and 8 had decreased to 7 and 4% respectively, while no latent mortality occurred among larvae collected on June 2 and 3. All smelt larvae collected in the discharge were dead with a large proportion of these larvae being severed or having eyes missing. In the 1981 larval fish entrainment study conducted at Nanticoke TGS (OHRD Report No. 82-55-K) approximately 40% of the larvae collected from the discharge were estimated to be physically damaged. The entrainment mortality calculated for the four days on which live larvae were collected from the forebay was 100% at both

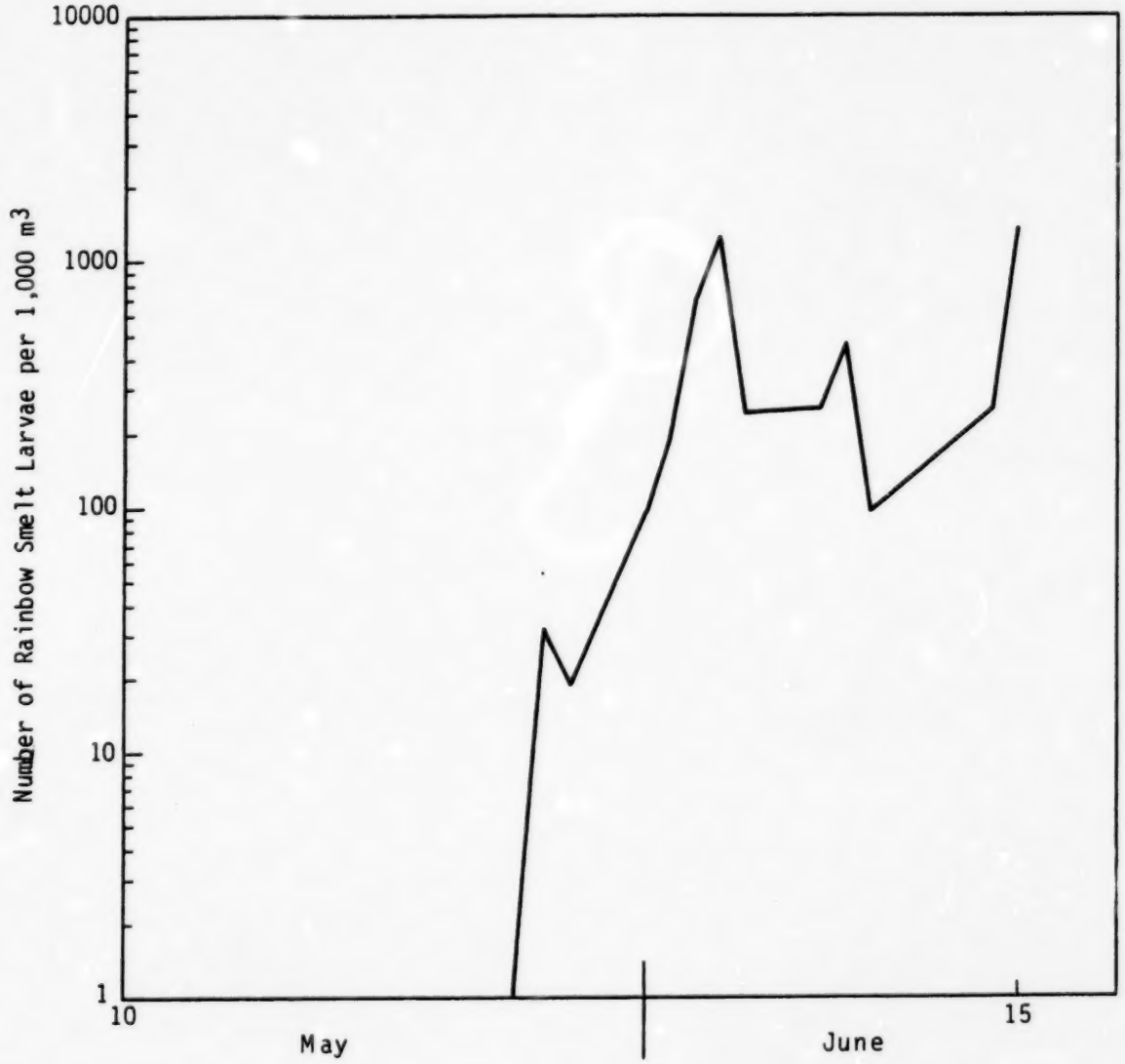

FIGURE 2

ESTIMATED DENSITIES (No.1000 m^3) OF RAINBOW SMELT LARVAE ENTRAINED AT NANTICOKE TGS, 1982

Table 3

Mortality of Rainbow Smelt following Plant Passage at Nanticoke TGS, 1982

Date	Average No of CCW Pumps Operational	Temperature °C Intake - Discharge	Total No Intake	% Alive Intake t=0	% Alive Intake t-24 h	Total No Discharge	% Alive Discharge t=0	% Alive Discharge t=24 h	Mortality (%) Due to Plant Passage Immediate	Mortality (%) Due to Plant Passage 24 h
May 27	12	14.5 - 27.0	1	0	0	10	0	0	ID	
May 28	12	15.5 - 27.5	5	0	0	71	0	0	ID	
May 31	9	15.0 - 26.5	1	0	0	4	0	0	ID	
June 1	12	14.5 - 26.5	10	0	0	20	0	0	ID	
June 2	12	10.5 - 24.0	13	7.7	7.7	42	0	0	100	100
June 3	14	11.5 - 23.0	13	30.8	30.8	84	0	0	100†	100†
June 4	14	12.5 - 23.5	8	0	0	70	0	0	ID	
June 7	9	13.0 - 24.5	54	14.8	7.4	69	0	0	100†	100†
June 8	11	13.5 - 20.5	83	6.0	3.6	35	0	0	100	100
June 9	12	14.5 - 25.0	26	0	0	45	0	0	ID	
June 10	12	15.0 - 27.0	17	0	0	7	0	0	ID	
June 11	12	13.0 - 24.0	21	0	0	32	0	0	ID	
June 14	7	14.5 - 25.0	2	0	0	18	0	0	ID	
June 15	11	12.0 - 24.0	7	0	0	7	0	0	ID	

† Proportion of dead animals in discharge samples significantly higher than in intake samples ($p<0.05$, 2 x 2 Contingency) (Chi-square test)

ID Indeterminate

observation periods. Chi-square tests performed on the data indicated that the proportions of dead larvae in the discharge samples on June 3 and 7, both immediately and 24 hours after collection were significantly ($P<0.05$) higher than the proportion of dead larvae in the intake samples.

4. DISCUSSION

The species composition of the larval fish collected at Nanticoke TGS in 1982 was similar to that found between April 1 and August 31, 1981, with rainbow smelt contributing to over 90% of the catch in both years.

In 1981 (Ontario Hydro Research Division Report No. 82-55-K) highest densities of larval smelt were found entrained from the third week of May to the third week in June. The densities of the larvae entrained in 1981 were comparable to those estimated to be entrained during the course of the present study.

The entrainment mortality of rainbow smelt larvae was 100% on all four occasions when estimates were obtained. Higher net approach velocities for discharge samples may account to some extent for the higher mortality in the discharge samples such that entrainment mortality estimates may be magnified although it is not known to what degree. A large proportion of the smelt larvae collected from the intake on June 2, 3, 7 and 8 were dead while all larvae collected from the intake on the remaining days were dead. It is not known whether the mortality of the larvae prior to condenser passage was due to handling mortality during sampling or whether the larvae were dead prior to collection (natural mortality). A similar observation was made in a report on larval fish entrainment at Pickering NGS (Ontario Hydro Research Division Report No. 82-85-K) on the high mortality of alewife larvae in intake samples.

O'Connor and Schaffer (1977) estimated net sampling survival of striped bass larvae to be from 40 to 64% at a water velocity of 15 cm/s, from 7 to 27% at 45 cm/s and none survived at 91 cm/s. The proportion of larvae that survived differed with the age of the larvae. Leslie (1983) studied the water velocities in the Nanticoke TGS intake and found the velocities at the 1 m depth to range from 18 to 44 cm/s. Velocities in the discharge channel based on calculated CCW flow rates at various pumping capacities (Data from Central Thermal Services), ranged from 50 to 94 cm/s. Thus if the sensitivity of larval smelt to netting was similar to that of striped bass, some net survival would be expected in the forebay and discharge samples. In a larval fish entrainment study conducted at Pickering NGS (OHRD Report No. 82-85-K) between 40 and 65% of the smelt larvae collected with nets from the forebay were alive and between 40 and 55% were alive in the discharge net samples.

If the mortality in the intake samples was largely due to sampling technique, it would appear that chances of survival through the condenser cooling system would be slim since considerable acceleration and shear stresses are encountered during passage through the station. This hypothesis is supported by Ulanowicz (1975) who suggested that the most destructive acceleration forces are short duration, high magnitude impulses from the impact of the organisms with a solid surface, and that the greatest shear stresses are encountered in the neighborhood of solid surfaces. Consequently, damage incurred during condenser passage would be expected to be greater than that suffered during sampling.

Crippen and Fahmy (1976) conducted icthyoplankton entrainment studies at Nanticoke TGS in 1976 and found higher mortalities in the discharge than in the intake. However, complete or near complete mortality occurred among both intake and discharge animals within 4 hours of sample collections. They suggested that the unexpected rapid rate of mortality among the intake larvae may reflect a biased selectivity of weak or dying larvae by the offshore submerged intake. Teleki (1976) who conducted entrainment studies on young-of-the-year smelt (larval and juvenile) at Nanticoke TGS in 1974 found 30% of the young-of-the-year fish from the forebay to be dead. He attributed half of these deaths to netting injuries and another 45% to mechanical abrasions and pressure changes inflicted during passage through the intakes to the forebay, while a very small percentage (1 or 2%) was estimated to be dead before entering the intake. He estimated that the total mortality from forebay to the effluent channel was 84%. Teleki's (1976) estimate was for both larval and juvenile smelt while Crippen and Fahmy's (1976) study, like the present study, was concerned with larval smelt only.

The smelt larvae and eggs that passed through the condenser cooling system at Nanticoke in 1981 (Ontario Hydro Research Divison Report No. 82-55-K) was equated to the progeny of 721,500 female adults. This was estimated to be equivalent to 1.1% of the traditional annual commercial catch in fishery District 4 of Lake Erie which includes the Nanticoke TGS area. Since no live smelt larvae or eggs were found in the discharge samples it can be assumed then that the entrained smelt are lost from the lake system. The assessed loss, however, is probably an overestimate of cropping by the Nanticoke TGS condenser cooling system since it is not known what proportion of the larvae were already dead before condenser passage. The 1981 study did not take into account those larval fish which passed from the intake forebay to the discharge channel through the tempering pumps. The extent of mortality incurred during tempering pump passage by smelt larvae is unknown. Thus, although all or nearly all smelt larvae entrained through the condenser cooling water system may be killed, not all smelt larvae entering the forebay are necessarily lost as many may pass through the tempering pumps unharmed.

5.0 SUMMARY AND CONCLUSION

1. Entrainment of larval rainbow smelt at Nanticoke TGS was monitored between May 11 and June 15, 1982. Highest density of entrained smelt larvae during this period was 1,306/1,000 m^3 (June 15).

2. Entrainment mortality estimates were obtained on June 2, 3, 7 and 8, 1982, the only days on which live larvae were taken in intake samples. On all four days mortality due to condenser passage was estimated at 100%. However, higher net approach velocities in the discharge may have accounted to some extent for the higher mortality in the discharge samples such that entrainment mortality estimates may be magnified.

3. A large portion of the larvae in the discharge samples were damaged with many having missing or injured eyes.

4. Assessments applying entrainment mortality of 100% to estimates of numbers of smelt larvae entrained probably overestimate the cropping effect of the Nanticoke TGS condenser cooling system since the proportion of live larval fish prior to plant passage is not known.

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